Neutron Detection and Characterization using Electron Cascade Multipliers

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THE INNOVATION:

A novel and versatile class of neutron detectors has been successfully demonstrated by NOVA Scientific, Inc. utilizing a new approach to neutron detection. Our detectors are being used in radiography applications and are under development for neutron scattering detector applications. We refer to these detectors as <u>*MxP's*</u>.

THE PRINCIPLE:

The fundamental concept of this new class of detectors is that a neutron reaction causes a release of secondary radiation within the solid-state *MxP* detector. The secondary radiation traverses one or more walls of the detector's extensive surface area. When the radiation emerges from the surface, it initiates a release of electrons. The resulting electrons are accelerated toward the readout and are greatly multiplied in number to provide a strong sharp signal.

Design Points:

• The MxP detector is based upon a *mature* microchannel plate (MCP) technology widely used for night vision components and ToF applications.

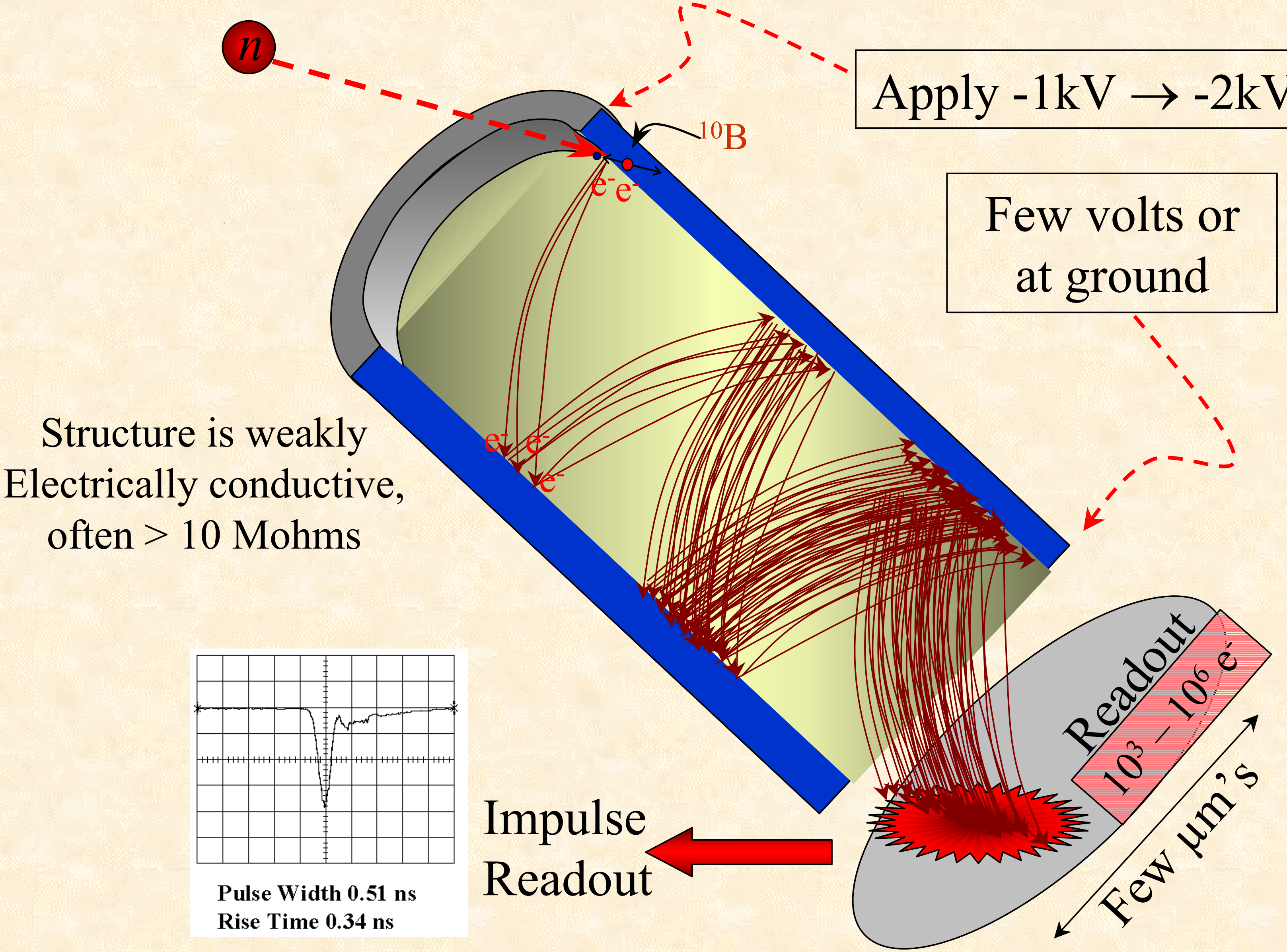
NOVA Scientific, Inc.
^{10}B enriched MCP

• Reactive *Nuclides* (e.g., ^3He, ^6Li, ^{10}B, $^{155,157}Gd$, etc.) are *incorporated* into the detector structure which efficiently absorb neutrons and produce secondary radiation at nearly one-to-one event yield.

• High detection efficiency and low noise requires that *the choice of reactive nuclide(s) in the bulk structure* be carefully controlled: NOVA has patent pending proprietary compositions.

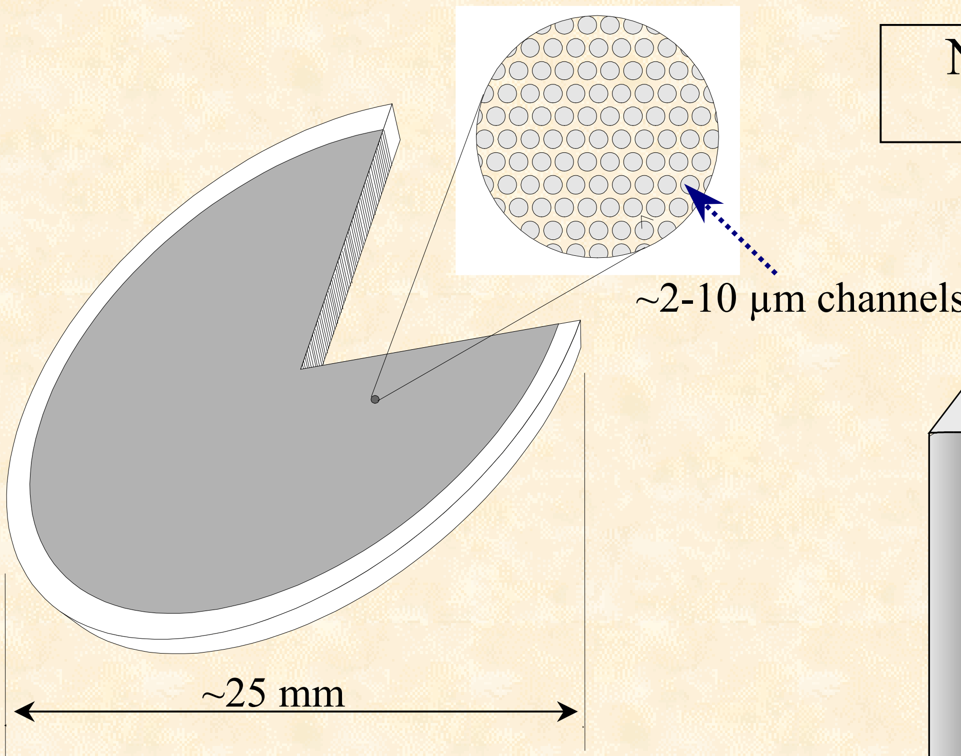
• Good spatial resolution requires that *the architecture of the detector be carefully considered:* NOVA has patent pending and proprietary structures.

Single Channel Cross Section within an MCP



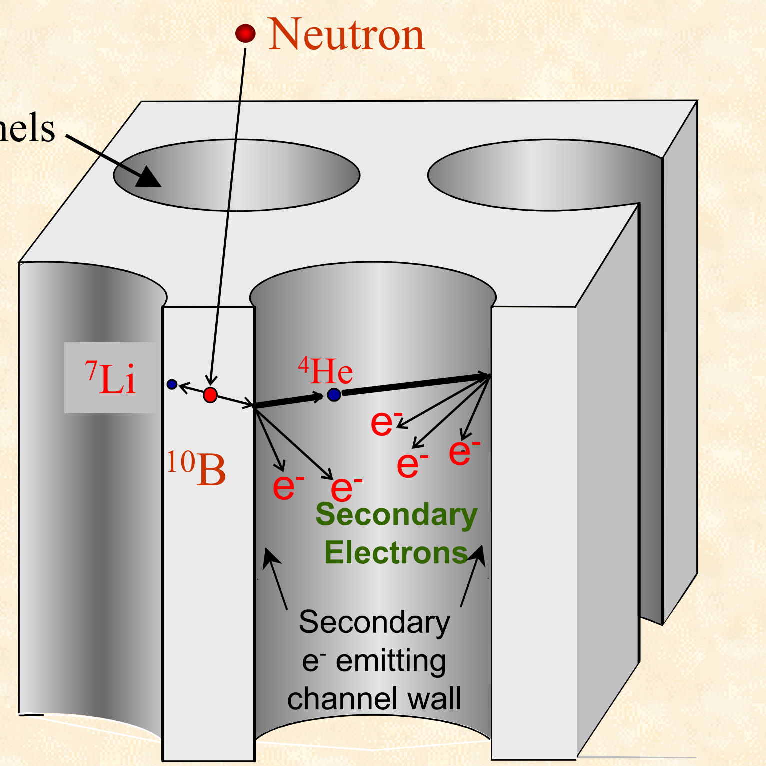
The Reaction Mechanism

Doped MxP Glasses Initiate Neutron Detection by Electron Pulse



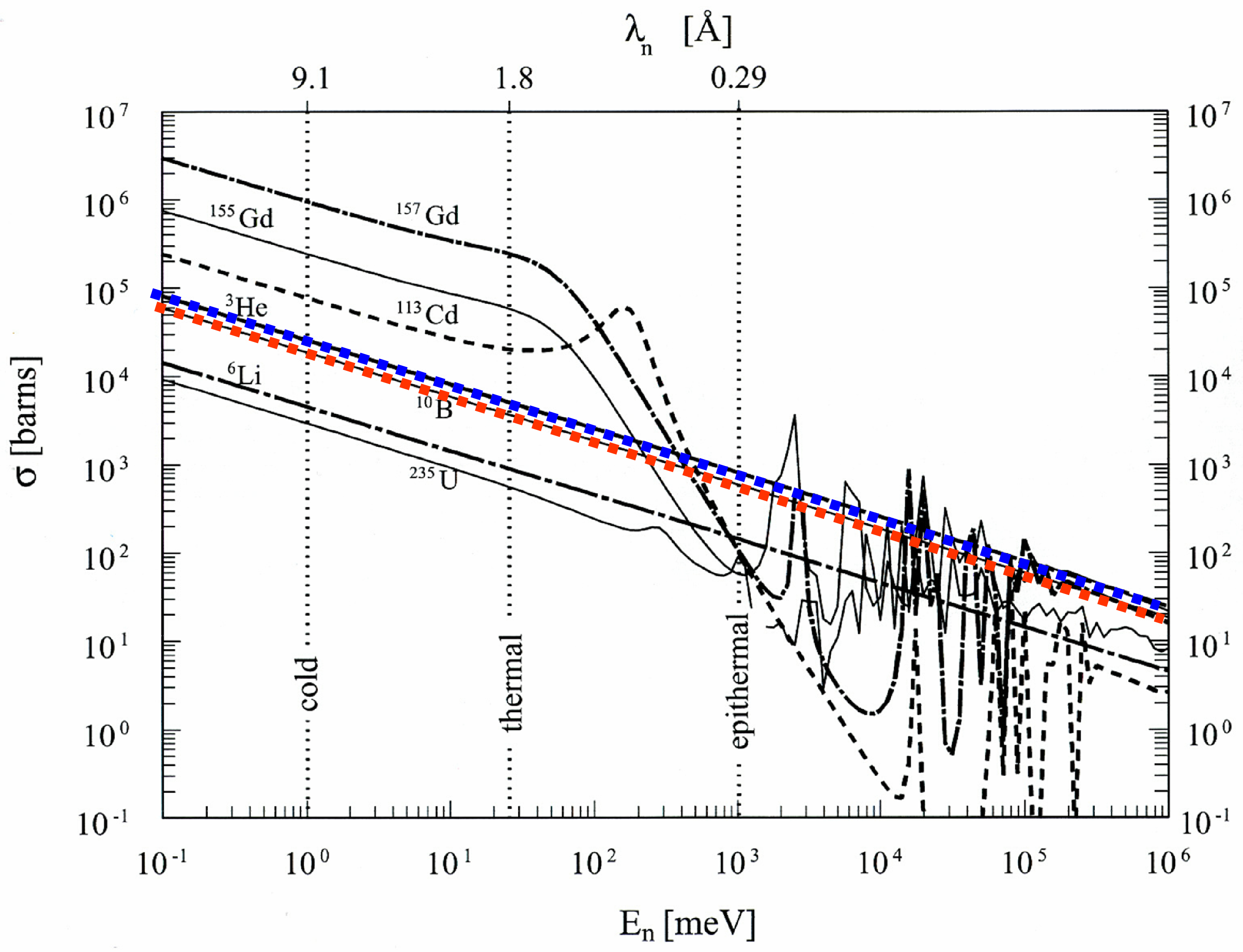
Example: MCP structure

Neutron Reaction Stimulates an Electron Cascade & Pulse



Nuclides for Neutron Capture & Conversion

Reactions Showing Significant Charged Particle Emission



Micrographs of Microchannel Plates (MCPs)

Traditional MCP Formats

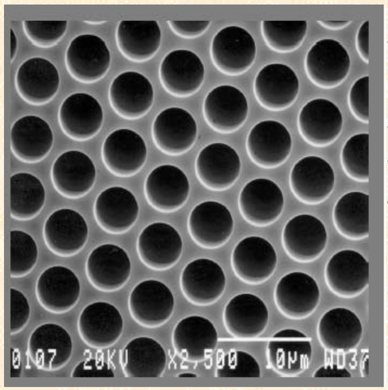


Image Courtesy of Burle Electro Optics

5 µm Channels

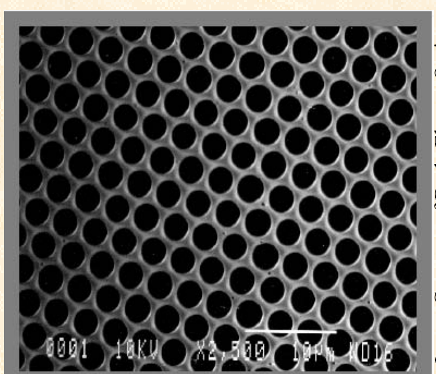
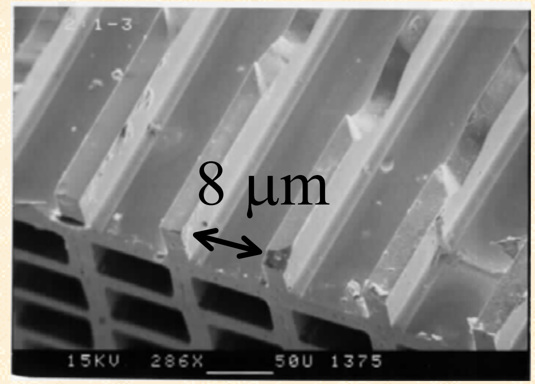


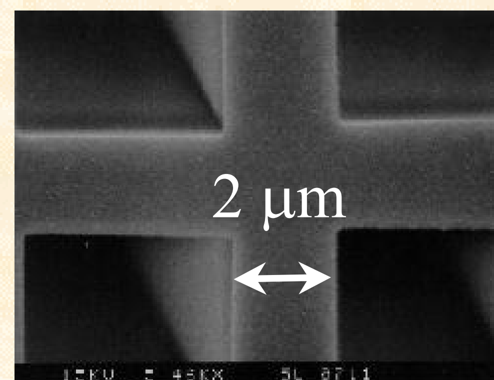
Image Courtesy of Burle Electro Optics

2 µm Channels

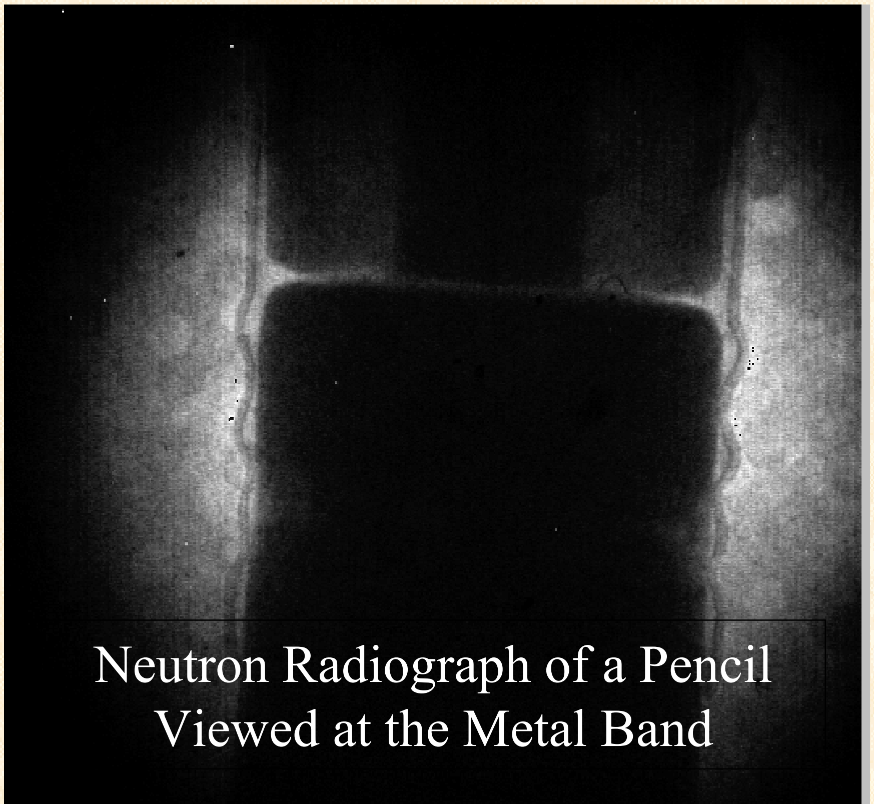
Square Channel MCP Format for Higher Detection Efficiency



Thin walls for good geometrical escape efficiency

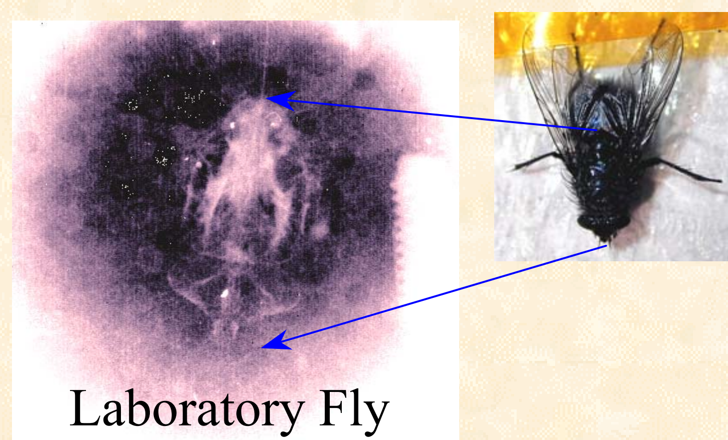


Existing NOVA Product is Based on MxP Technology: High Resolution, Real-Time Radiography



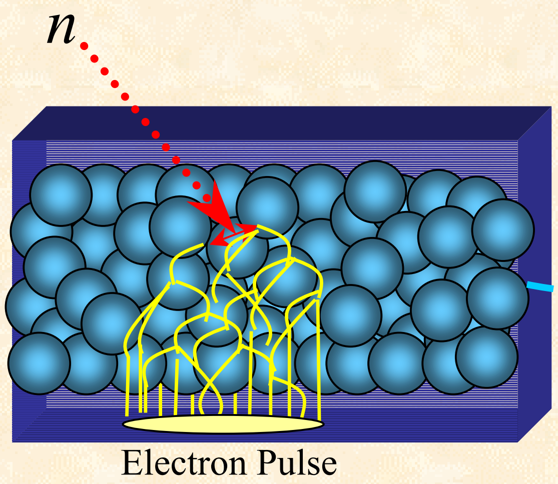
Neutron Radiograph of a Pencil
Viewed at the Metal Band

- High resolution <30 µm
- Real time imaging
- Pulse counting option
- Good conversion efficiency

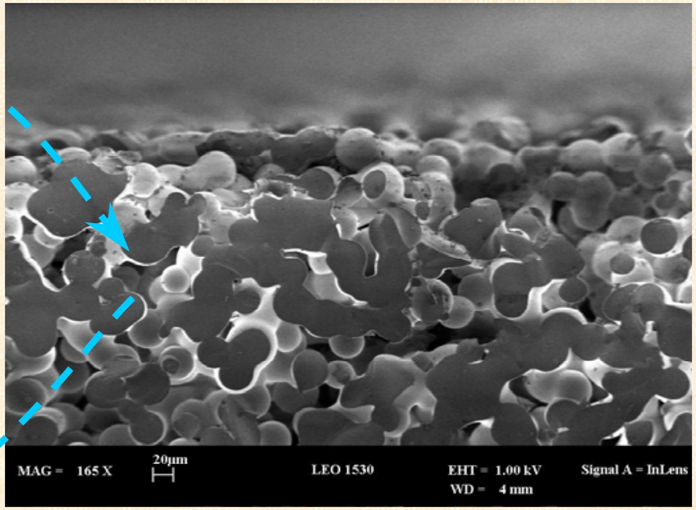


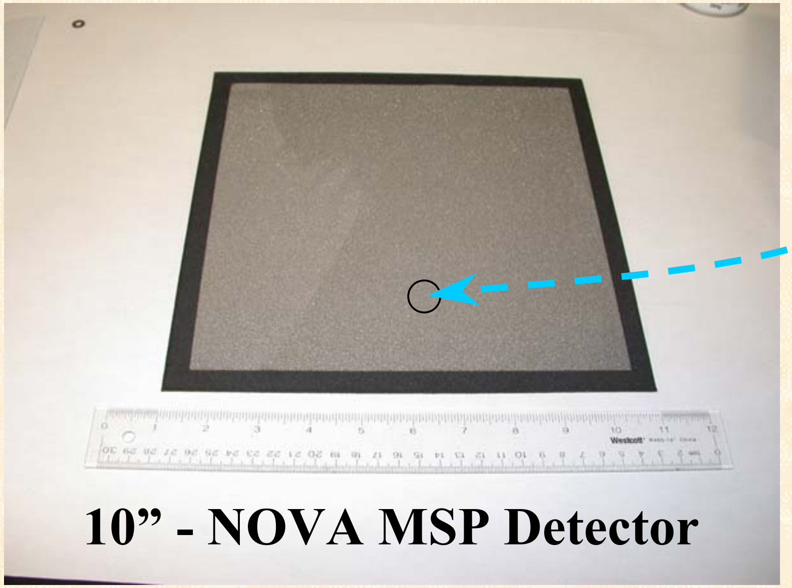
Laboratory Fly

NOVA's Microsphere Plate (MSP) Detector



A side cut micrograph of NOVA's microsphere plate showing fusing of spheres and open structure



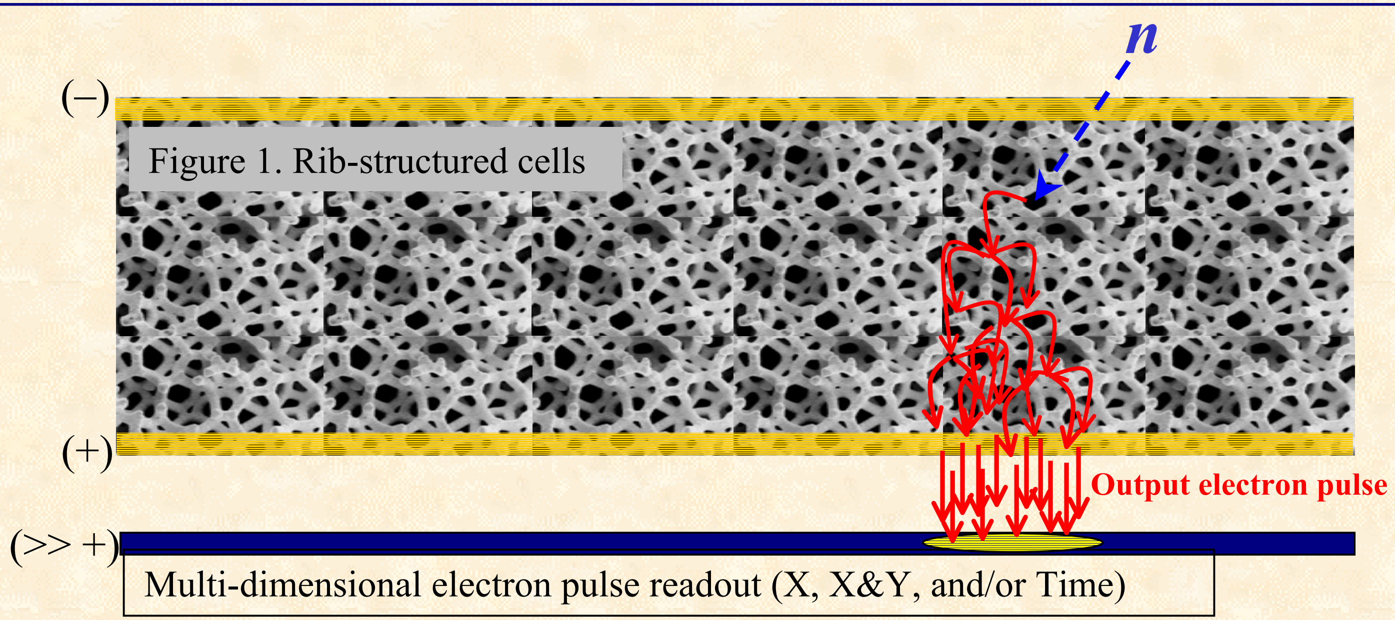


10" - NOVA MSP Detector

- ❖ Large areas
- ❖ Contour to optics
- ❖ Fast response (< 1 ns)
- ❖ Good resolution

NOVA’s MicroReticulated Plate (MRP) Detector

– a multi-dimensional detector that converts individual neutrons to an electron pulse, multiplied by cascading surface interactions. The principle is analogous to the operation of a microchannel plate (MCP) detector. The distinguishing feature is the physical structure: an open-cell or reticulated design of proprietary composition. Illustrated below, the cell sizes are not shown to scale. The “rib” dimensions are designed for the specific doping nuclide (such as ^{6}Li, ^{10}B, Gd…) The ribs are flattened to provide good geometric escape efficiencies for the neutron conversion particles.

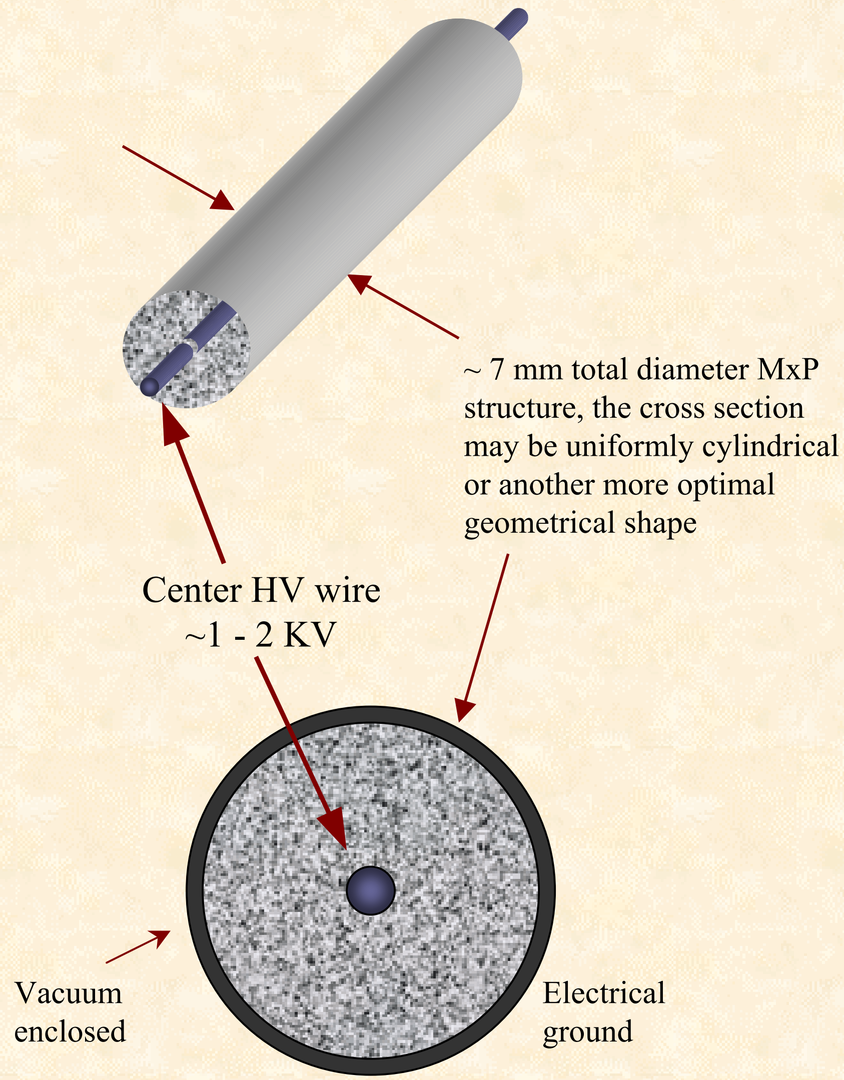


Readout Methods

- ❖ Neutron Counting: Metal Anode
- ❖ Field Imaging: Phosphor Screen
- ❖ Both: Position Sensitive Detectors
  - ✓ Cross line delay anodes (XLDA's)
  - ✓ Single and Multi-wire Particle Counting
  - ✓ & a variety of other possibilities
- ❖ Software processing for centroid positioning and time of flight applications

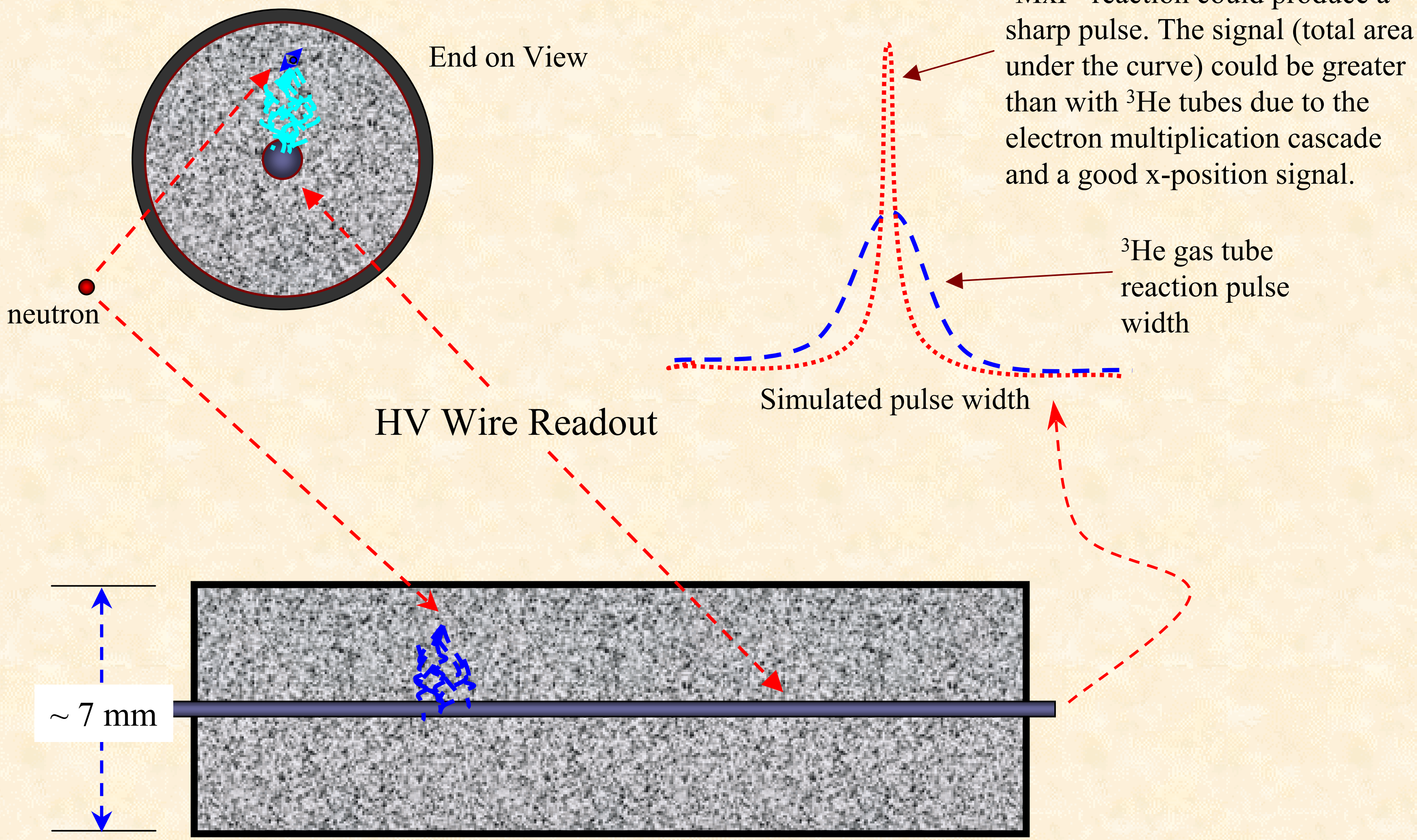
MicroReticulated (MRP) Plate Detector in a Cylindrical Format

As in the previous illustration, the structure is in a reticulated form. However, the neutron-stimulated electron cascades are attracted to the center wire instead of a X-Y sensitive plate. Here, the readout would be analogous to that used in the traditional ^{3}He gas tube detector. Because the voltages are similar to existing ^{3}He detectors, the detector might be installed as a straight substitution for the ^{3}He gas tube commonly used in existing neutron instruments. The electronic readout could be further optimized to take advantage of the faster MxP response characteristics.



Cross Sectional View

MicroReticulated Neutron Detector



End and side cut views of a *cylindrical* format detector showing the neutron reaction, the ensuing electron cascade, and the pulse collection on HV wire.

Detector Properties:

- High Conversion Efficiency – comparable to ^3He
- Good – High Spatial Resolution – 500 ~ 30 μm
- Strong Signal – 10^3 to $>10^6$ electrons per pulse
- Low γ/n Noise ~ $<10^{-4}$, and still improving
- Faster response and dynamic range (local and global) than existing large area readouts can handle (~10 MHz)
- Easily shaped to optical conditions – regular or irregular
- Scalable to large areas - mm^2 to $>> m^2$

Summary:

Development of a New Class of Neutron Detector: NOVA MxP's

- ❖ Solid state construction
- ❖ Simple design with …
  - ✓ Versatile size
  - ✓ Versatile shape
- ❖ Efficient neutron conversion (~ black absorber for thermal neutrons)
- ❖ Fast & strong signal from electron multiplier cascade pulse
  - ✓ Sharper pulse duration (narrower)
  - ✓ Applicable to ToF applications
- ❖ Excellent position resolution
- ❖ Acceptable signal-to-noise response & improving
- ❖ Readout using existing or custom optimized electronics
- ❖ Devices can form large area x, xy &/or temporal resolved detectors